RESEARCH PAPER
FOOD SCIENCE RESEARCH JOURNAL
ISSN-0976-1276 ■ Visit us : *www.researchjournal.co.in*
Volume 11 | Issue 2 | October, 2020 | 158-168
DOI : 10.15740/HAS/FSRJ/11.1/158-168

Development of jackfruit leather and its shelf-life analysis in different packaging materials

Ninisha Babu, Ammu Dinakaran, Maya Raman, Akshaya Ravindran, T.V. Sankar and T. K. Srinivasa Gopal

Post-harvest loss is very common in seasonal fruits due to its high perishability even under refrigerated conditions. Value addition and processing is the best solution to overcome this problem and it also ensures the availability of the product round the year. This study is to develop jackfruit leather that replicates the natural fruit taste and is shelf stable at room temperature (28 ± 2°C). The product contributes 3.63Kcal/g to the energy requirement and is rich in minerals like potassium and sodium (7442µg/g and 1842µg/g, respectively). Sorption isotherm studies showed a sigmoid characteristic for the product. It has a critical moisture content of 48.39±0.44% with respect to 96% relative humidity and a water activity of 0.47. The product was packed in different packaging materials like 220-gauge polyethylene laminated with 50-gauge metalized polyester (Met PE) and 150 gauge Biaxially Oriented Poly Propylene (BOPP) laminated with 50-gauge polyester to study and compare its shelf-life in both the packaging materials at room temperature (28 ± 2°C). Physical and chemical parameters of the product was analyzed during the period of storage and the results revealed a shelf stability for 90 days for the product packed in both the packaging materials.

Key Words : Jackfruit leather, Value addition, Sorption isotherm, Water activity, Shelf- life

How to cite this article : Babu Ninisha, Dinakaran, Ammu, Raman, Maya, Ravindran, Akshaya, Sankar, T.V. and Srinivasa Gopal, T.K. (2020). Development of jackfruit leather and its shelf-life analysis in different packaging materials. *Food Sci. Res. J.,* **11**(2): 158-168, **DOI : 10.15740/HAS/FSRJ/11.2/158-168**.

INTRODUCTION

Jackfruit is a common fruit of the Indian state, Kerala, which was recently declared as the state fruit of Kerala. It is also the state fruit of another Indian state Tamil Nadu and the national fruit of Bangladesh (Matin, 2015 and Subrahmanian *et al.,* 1997). The initiative aims for the improvement in the market value of the fruit and its value added products. The fruit is commonly grown in almost every households of Kerala without any use of fertilizers or chemicals and thus the fruit is claimed to be organic, natural and tasty. The consumption of jackfruit is common in the South and Southeast Asian countries (Janick and Paull, 2008). With reference to the nutritional value of jackfruit it is considered as a partial solution for food security in developing countries.

The ripe jackfruit is naturally sweet and reports claim the fruit has a pineapple like or banana like flavour. It is a fruit that is used for many traditional preparations in the southern states of Kerala. The fruit bulbs are also eaten as such. It is also found in the markets of Southeast Asia.

MEMBERS OF RESEARCH FORUM

Author for correspondence :
Ammu Dinakaran, Center of Excellence in Food Processing Technology, Kerala University of Fisheries and Ocean Studies, Panangad, **Madavana (Kerala) India**
Email: ammu.dinakaran@gmail.com

Associate Authors' :
Ninisha Babu, Maya Raman, Akshaya Ravindran, T.V. Sankar and T.K. Srinivasa Gopal, enter of Excellence in Food Processing Technology, Kerala University of Fisheries and Ocean Studies, Panangad, **Madavana (Kerala) India**

Canned jackfruit is also available as a vegetable in the export market. It is available in the ready to cook form in different markets throughout the world (Goldenberg, 2014; Brian Kateman, 2019 and Morton, 2016).

Drying is one of the ancient method of preservation that is being widely used even nowadays. The principle behind the preservation activity of drying is the reduction in the amount of water available for degradation reactions (Muliterno *et al*., 2017) Heat is used for vaporizing the water present in food and then remove the water vapor from the surface of food (Cruz *et al.*, 2015) Drying is a method of preservation that has wide application for the preservation of fruits and vegetables (Seow *et al.*, 1988). Drying helps in reducing the expenditure for storage and transportation by avoiding the use of refrigerated systems. It also facilitates food handling by reducing the space required for storage and transportation (Guine *et al.*, 2008 and Guine, 2010).

Fruits are highly perishable even on storage under refrigerated conditions.Their harvest season is also very short which makes it essential to preserve the fruits or develop fruit based value added products to ensure its availability round the year. Manufacture of fruit leathers is a method for fruit preservation (Huang and Hsieh, 2005 and Maskan, 2002). Fruit leather is a dehydrated product prepared out of fresh fruit pulp or fruit juice concentrate. It is a leather like sheet and is also known as fruit bar or fruit slab. Fruit pulp is spread on flat trays and moisture is removed by different methods of drying. Fruit leathers usually have a chewy texture and also replicates the original flavour of the fresh fruit (Raab and Oehler,1976; Ayotte,1980 and Moyls, 1981). Different fruit leathers are available in the market and in this study an attempt was made to develop jackfuit leather from the variety of jackfruit (*Artocarpus heterophyllus*) which is commonly known as 'varikka'.

METHODOLOGY

Materials:

Jackfruit (*Artocarpus heterophyllus)* commonly available in Kerala, India are two different varieties namely 'Koozha' and 'Varikka'. Among these varieties 'Varikka' which has firm fleshed fruit bulbs were chosen for the study. It was purchased from the local market (Cochin, Kerala, India). The analytical grade chemicals used for the study were obtained from HiMediaÒ and Sigma-AldrichÒ (Cochin, Kerala, India). The work was carried out at Centre of Excellence in Food Processing Technology, Kerala University of Fisheries and Ocean Studies, India.

Packaging materials:

The storage stability of the product was studied in different packaging materials like 220-gauge polyethylene laminated with 50-gaugemetalized polyester (Met PE) and 150 gauge Biaxially Oriented PolyPropylene (BOPP) laminated with 50-gaugepolyester.

Sample preparation:

Jackfruit (Varikkachakka) which has ripened to the required level was used. The fruit bulb which has a firm texture without seeds were collected and pressure cooked along with corn flour and water as per the quantity mentioned in Table A. The protocol for the preparation of jackfruit leather was chosen as per the work of Che Man and Taufik (1995). Honey was added to the cooked bulbs and was grinded to form a smooth pulp. Potassium metabisulphite and sodium benzoate was added within the permissible levels. The pulp was then spread on trays coated with butter and dried at 52°C and 1.5m/s air velocity for 24h in a tray drier (Excalibur food dehydrator).

Table A: Formulation of jackfruit leather

Composition	Jackfruit leather (100g)
Jackfruit bulb (g)	64.9
Corn flour (g)	3.2
Honey (g)	2.6
Water (g)	29.2
Potassium metabisulphite (g)	0.03
Sodium benzoate (g)	0.01

Chemical characterization

The proximate composition of jackfruit leather was determined according to AOAC (2000). The moisture (method 925.10), ash (method 923.03), protein (N x 6.25) (960.52) (KEL PLUS digestion (KES 06 R) and distillation systems (DISTYL EM S), M/s Pelican Equipments, Tamil Nadu, India) and lipid contents (2003.05) (SOCS PLUS SCS2 R, M/s Pelican Equipments, Tamil Nadu, India) were determined. The total dietary fibre (TDF) was determined using FIBRA PLUS FES 02 E (M/s Pelican Equipments, Tamil Nadu, India). The caloric value of jackfruit leather was calculated using the Atwater factor formula, where by the major biochemical constituents were converted into calorific values using standard calorific equivalents, *i.e.*, 5.65, 9.45 and 4.20 for proteins, lipids and carbohydrates, respectively (Dare and Edwards, 1975).

Calorific value (kcal/g) = (5.65 x P + 9.45 x L + 4.20 x C) / 100

Estimation of minerals:

ICP-OES was used for the estimation of minerals in jackfruit leather. Wet digestion was done for sample preparation. 1g sample was digested in 5ml concentrated nitric acid solution by heating at 70°C until a clear solution was obtained using a heating mantle (ANTECH, AN-MSH 680, India). The solution was cooled and 5ml of 30% (v/v) H_2O_2 solution was added. Deionized water was used to make up the solution to 25ml. The Optima 8000 ICP-OES Spectrometer (Perkin Elmer, India) was used for measuring the sodium, potassium, calcium, magnesium, iron, copper and zinc. A RF power of 1500 watts, a plasma gas flow rate of 8L/min, a shear gas flow rate of 25 L/min and a nebulizer gas flow rate of 0.7L/min. Prepared sample solutions were introduced into the plasma using auto sampler. Nebulizer and a cyclonic type spray chamber at a flow rate of 1ml/min. Analytical line of Na 589.021nm, K 766.490nm, Mg 279.081nm, Ca 315.889nm, Fe 259.942nm, Cu 324.756nm and Zn 213.861nm, were selected and measured. (Raman *et al.*, 2019).

Sorption isotherm studies:

Equilibrium moisture content of jackfruit leather was determined using static gravimetric method (Jowitt *et al.*, 1983) at room temperature (28±2°C) under different conditions of water activity. Glass desiccators were used as chambers with different water activity conditions. Saturated salt solutions corresponding to a range of water activities from 0.11 to 0.96 were prepared and filled in desiccators to achieve the required relative humidity condition. The list of saturated salt solutions and the corresponding relative humidity is given in Table B. The corresponding relative humidity achieved in desiccator was checked using a hygrometer. The samples (approximately 2g) in triplicates were weighed and placed in each desiccator and closed tightly to maintain the condition and placed in ambient temperature. The samples were weighed every 24 hours during the entire equilibration period (AOAC, 1990).

Table B: List of saturated salt solution

Saturated solution	Relative humidity
Lithium chloride	12
Potassium acetate	22
Magnesium chloride	32
potassium carbonate	43
Sodium dichromate	52
Magnesium nitrate	53
Sodium nitrite	64
Sodium chloride	75
Ammonium sulphate	80
Potassium chloride	84
Potassium nitrate	92
Potassium sulphate	96

Drying characteristics:

Heat and moisture transfer occurs simultaneously during the process of drying (Sahin and Dincer, 2005). The drying characteristics of the jackfruit pulp was determined by weighing the samples in pre-weighed trays every 30 minutes during the period of drying until desired moisture level was obtained. The hot air drying experiment was done at 52°C temperature and 1.5m/s air velocity. (Wankhade *et al.*, 2013).

Storage studies:

The jackfruit leather was packed in different packaging materials like 220-gauge polyethylene laminated with 50-gauge metalized polyester and 150 gauge BOPP laminated with 50-gauge polyesterand stored at room temperature to estimate the shelf stability of the product in both the packaging materials. Different properties of the product were analyzed every 15 days until spoilage occurred.

pH:

The changes in pH of jackfruit leather packed in two different packaging materials was measured by a pH meter (Eutech Instruments pH 510, Cyber Scan, India) using Approved Methods (AACC, 2000). Samples were cut and mixed with distilled water in 1:10 ratio and stirred for 30 min. The supernatant was collected and pH values were recorded. pH was measured for samples packed in different packaging materials every 15 days.

Titratable acidity:

Jackfruit leather packed in different packaging materials were taken up for analysis every 15 days. The changes that occurred in titratable acidity was analyzed to determine the total acid concentration. Although citric acid and malic acid are the predominant acids present in jackfruit studies have reported that the amount of malic acid decreased and citric acid has increased with ripening of jackfruit (Ong *et al.,* 2006). Thus, titratable acidity was expressed in terms of citric acid as g/100g of citric acid. A known quantity of sample was homogenised and titrated against a standard base using phenolphthalein as indicator to neutralize the amount of acid present in the sample (Tyl and Sadler, 2017).

Total sugar, reducing sugar and non-reducing sugar:

The amount of total sugar and reducing sugar present in jackfruit leather was determined using fehlings solution as described in Lane and Eynon (1923) method and non-reducing sugar was determined using Hortwitz (1960).

Non-reducing sugar (%) = (total sugars % – reducing sugars %) × 0.95

The same method was adopted to determine the changes that occurred in the sugar composition during the period of storage. Samples stored in two different packaging materials were analyzed every 15 days.

Texture profile analysis:

The textural characteristics of jackfruit leather was analyzed using a Shimadzu Texture Analyzer (EZ LX HS). Trapezium software was used to determine the parameters like Hardness 1, Hardness 2, Cohesiveness, Springiness and Chewiness. The texture analyzer is equipped with a load cell of 100N. Cylindrical probe of 35 mm diameter was used at a test speed of 50mm/ minuteand a trigger force: 1kgf. The samples were Compressed to an extent of 50 per cent. The changes in the textural parameters of the samples were analyzed by subjecting it to texture profile analysis every 15 days (Al Hinai *et al.,* 2013 and Gujral and Khanna, 2002).

Colour:

The CIE Lab coordinate of the jackfruit leather was determined using Color Flex EZ (Hunterlab, USA) reporting luminosity (L*), redness (a*) and yellowness (b*). The changes that occur in the product during the period of storage is easily reflected in the appearance. Thus the L*, a* and b* values for the product was measured every 15 days.

Sensory evaluation:

Consumer acceptance of the product was analyzed with the help of trained sensory panel who rated the product using a ten-point hedonic scale were 1 and 10 represents extreme dislike and extreme like, respectively. The same panel members were asked to monitor the changes that the product has undergone during storage by conducting sensory evaluation every 15 days.

Statistics:

All results are expressed given as means and standard deviation. Analysis of variance was conducted using one-way ANOVA and Tukey test by pair-wise analysis with significance defined at $p < 0.05$.

Observations and Assessment

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Chemical characterization:

The proximate composition of the fresh jackfruit leather is given in Table 1. The results show that it is a high carbohydrate product and can contribute 3.68 Kcal/ g to the energy requirement. The proximate composition was found to be similar and comparable with the values reported by Che Man and Taufik (1995) and Cheman (1996). In these studies, work was done using jackfruit variety available in Malaysia.

Table 1 : Chemical composition of jackfruit leather

	Chemical parameters (g/100g)
Moisture	12.2 ± 0.26
Ash	3.5 ± 0.3
Fat	1.4 ± 0.4
Protein	4.6 ± 0.4
Carbohydrate	78.30 ± 0
Fibre	3.9 ± 0.4

Estimation of minerals:

The mineral content of the product was determined using ICP-OES and the quantity of each mineral present is shown in Table 2. Jackfruit leather was found to have high potassium content which quantifies to 7442.2µg/g. Potassium helps in the osmoregulation of cells (Antoine

Table 2 : Minerals present in jackfruit leather

	Mineral content (μg/g)
Potassium	7442.2
Sodium	1842.1
Magnesium	869
Calcium	445.3
Iron	101.2
Chromium	10.8
Copper	4.4
Zinc	3.8
Cadmium	0.1

et al., 2012). The adequate intake (AI) of potassium for females and males of age 31 to 50 is 4700mg/day (Appel *et al.*, 2005 and Koubova *et al.*, 2018). Sodium is an essential part of the diet since it serves as a blood pressure regulator. The AI value was reported as 1500mg/day for females and males aged 31 to 50 (Appel *et al.*, 2005) and the amount of sodium present in jackfruit leather was 1842.1μg/g. The amount of magnesium present in jackfruit leather was 869μg/g and its recommended dietary allowance (RDA) for females and males are 320 and 420mg/day. Deficiency of magnesium can lead to cardiac malfunction and muscle weakness (Institute of medicine, 1997). Calcium with RDA values for females and males aged 31 to 50 of 1000mg/ day and Iron with RDA values for females and males are 18 and 8 mg/day are also essential parts of the diet. Jackfruit leather was found to have 445.3 μg/g and 101.2 μg/g of calcium and iron, respectively. Calcium is essential for muscle contraction and hormone secretion and iron is a major component of heme protein (Institute of medicine,1997 and Trumbo, 2001). Trace quantities of chromium, copper, zinc and cadmium were also found in jackfruit leather. Chromium helps carbohydrate metabolism and copper is reported as a constituent of redox enzymes (Morgano *et al.*, 2011).

Sorption isotherm studies:

Moisture sorption isotherms have a wide range of application in the area of research on foods. It can be used to predict the shelf-life of the product, calculate the drying time, to model the moisture changes that occur during storage (Labuza, 1968 and Al-Muhtaseb *et al.*, 2002). The sorption isotherm of jackfruit leather (Fig. 1) showed sigmoid characteristic which is similar to the results obtained for other sorption studies (Ikhu-Omoregbe, 2006). The moisture sorption isotherm clearly shows that the critical moisture content of jackfruit leather is 48.39 ± 0.44 per cent with respect to 96 per cent relative humidity. The water activity of the product is 0.47. Water activity plays which is a factor depending upon the storage temperature, relative humidity and moisture content of the product plays an important role in the shelf stability of the product. It can enhance and deteriorate the rate of microbial and physico-chemical deterioration in the product. Lower water activity enhances the shelf stability of the product (Sanni,1996; Ukhun and Dibie, 1991; Ofuya and Akpoti, 1988 and Chuzel and Zakhia, 1991).

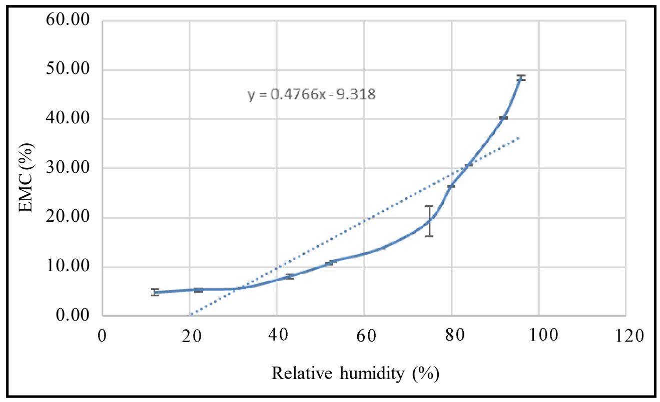

Fig. 1 : Moisture sorption isotherm of jackfruit leather at room temperature

Drying characteristics:

The metabolic activity of fruits and vegetables are high when compared to other plant products like seeds which can be attributed to the high moisture content. The increased moisture content is also the reason which makes them highly perishable. The decrease in moisture content to a level that does not allow the growth of microorganisms is the only alternative to improve their shelf-life and drying is a method of preservation that helps to reduce the moisture content and thereby retard the chemical and microbial spoilages that can occur in the product (Maskan *et al.*, 2002; Krokida and Marinos-Kouris, 2003). Hot air drying is acommonly used method for moisture reduction and it gives uniform, hygienic and attractively coloured products rapidly (Doymaz, 2004). The process of drying should ensure the conditions like short drying time, low energy consumption, high rate of water removal to obtain best quality dried products (Chin *et al.*, 2015). The Fig. 2 shows the drying curve obtained for the drying of jackfruit pulp which had a moisture content of 34.61 per cent wet basis to jackfruit leather having a moisture content of 12.58 per cent as on basis. The figure shows a drying time of 6 hours at 52°C temperature and 1.5m/s air velocity. The curve shows that the rate of decrease in moisture content is rapid initially and then decreased. Similar results were reported in studies on drying of apple slices, Kiwi etc. the decrease in the free moisture content during drying leads to decrease in the drying rate (Sacilik and Elicin, 2006; Chin *et al.*, 2015 and Unal and Sacilik, 2011).

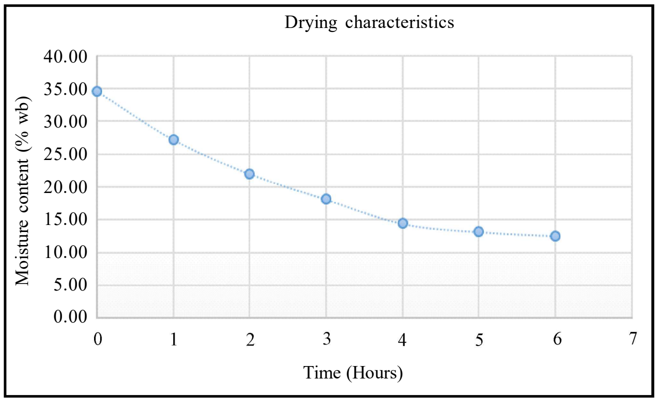

Fig. 2 : Drying characteristics of jackfruit leather

Storage studies

pH and titratable acidity:

The jackfruit leather packed in 2 different packaging materials and stored at room temperature was analyzed to determine the shelf-life. Fig. 3 shows the changes in pH and Titratable acidity during the period of storage. The pH values indicating the acidity level shows a slight decrease during storage upto 90 days which is not significant at P<0.05 which indicates a storage stability at room temperature for 90 days. On the 105th day of storage an increase was observed which was also not significant at P < 0.05. Spoilage in the form of mold growth was observed on 105th day. In the study of Cheman and Sanny, 1998 on jackfruit leather a fluctuating trend during the storage and an increase at the end of storage period was reported. Durian leathers were reported to have a fluctuating pH during storage (Irwandi *et al.,* 1998). In paw paw leather pH was reported to be fluctuating in nature and in guava leather a decreasing trend was observed. The decrease in pH can be due to fermentation by micro-organisms (Babalola *et al.*, 2002). The product packed in both the packaging materials showed similar results without any significant difference at P<0.05.

(Ong *et al*., 2006), has reported a titratable acidity

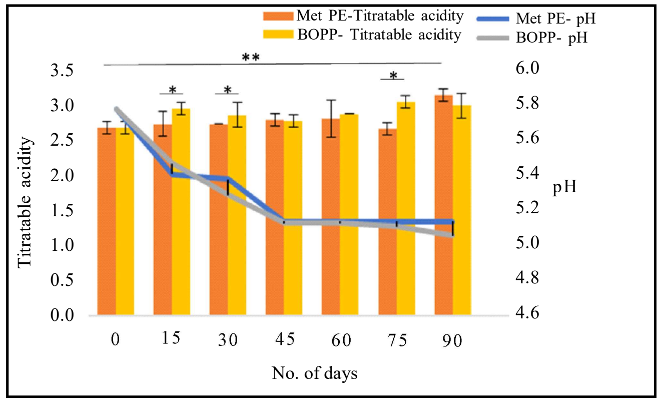

Fig. 3 : Changes in pH and titratable acidity

in the range 0.3 to 0.9 per cent for jackfruit whereas Selvaraj and Pal (1989) has reported 0.1 to 0.2 per cent titratable acidity. Compared to these results the initial titratable acidity of jackfruit leather was much higher (2.69±0.09). This change can be due to the difference in variety of fruit. The trend observed in pH was reflected in results obtained for titratable acidity showing an increase during the storage period. The samples packed in metallized polyester showed an increase during the storage period which was not significant at P<0.05 upto 75 days and showed a significant increase on the 90th day (P<0.05). In the case of samples packed in BOPP the increase was significant from the 15th day onwards. Significant difference at P<0.05 was observed between the titratable acidity of samples packed in metallized polyester and BOPP on 15th, 30th and 75th days. On the 105th day of storage a sudden decrease in titratable acidity which was significant at P<0.05 was observed in both the packaging materials. This change can be due to the mold growth observed on the sample (Sadler and Murphy, 2010).

Total sugar, reducing sugar and non- reducing sugar:

The amount of sugars was found to be more in the product initially which further showed a decreasing trend. The trend observed during the period of storage is given in Fig. 4. The decrease in sugars in the product packed in both packaging materials on the 15th day was not significant. Whereas there was significant difference (p<0.01) in the sugar content from 30th day onwards. After 15 days fermentation started and hence, the amount of reducing sugar and total sugar decreased. Further non-reducing sugars was not hydrolyzed to reducing sugar.

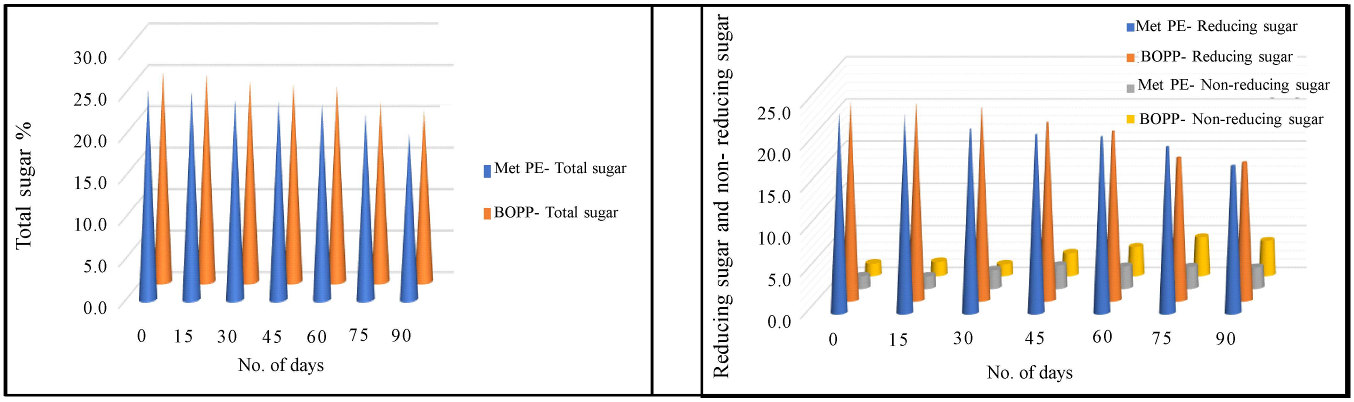

Fig. 4: Changes in total sugar, reducing sugar and non- reducing sugar

Non-reducing sugars can be sucrose, raffinose, etc. which did not hydrolyze during the later stages of storage or did not undergo inversion to form glucose and fructose. Since, mold growth was observed on 105th day, there was a drastic fall in total sugar, reducing sugar and non-reducing sugar. Similar pattern was observed for guava and peach fruit concentrate and juices (Chemann and sanny, 1998). The products packed in both the packaging materials showed similar changes during storage

Colour:

The Table 3 shows the changes in L*, a*, and b* values of the product. The L*, a* and b* values started showing significant decrease ($p<0.05$) from the 15th day onwards during the period of storage in both the packaging materials. On comparing the changes in colour of the product with respect to the packaging material used, a significant difference ($p<0.05$) in the L* and b* values were observed throughout the storage period whereas no significant difference ($P<0.05$) was observed on the 15th day and 45th day. The changes observed is in accordance with results previously reported and is reported to be due to the non-enzymatic browning reaction and extend of available oxygen (Rao and Roy, 1980 and Chemann and Sanny, 1998).

Texture profile analysis:

The textural changes that occurred in the product

Table 3 : Colour changes observed in the jackfruit leather during storage

Storage time in days	Type of packaging material	L*	a*	b*
0		54.46 ± 0.19	16.36 ± 0.14	46.12 ± 0.18
15		50.58 ± 0.15	15.78 ± 0.11	45.70 ± 0.17
30		49.54 ± 0.41	14.67 ± 0.03	44.78 ± 0.44
45	Metallised polyester /LDPE	48.25 ± 0.62	14.50 ± 0.09	39.06 ± 0.43
60		46.00 ± 0.39	14.30 ± 0.03	35.71 ± 0.41
75		44.47 ± 0.07	13.87 ± 0.02	33.06 ± 0.22
90		42.00 ± 0.30	13.56 ± 0.1	31.95 ± 0.25
105		41.54 ± 0.35	13.16 ± 0.07	28.42 ± 0.07
0		54.46 ± 0.19	16.36 ± 0.14	46.12 ± 0.18
15		49.38 ± 0.20	15.70 ± 0.08	42.95 ± 0.52
30		46.34 ± 0.33	15.15 ± 0.09	39.37 ± 0.49
45	BOPP	44.68 ± 0.23	14.66 ± 0.17	35.17 ± 0.24
60		43.89 ± 0.24	14.07 ± 0.11	30.24 ± 0.13
75		43.43 ± 0.36	13.52 ± 0.17	29.50 ± 0.21
90		41.03 ± 0.29	13.21 ± 0.14	27.65 ± 0.29
105		37.32 ± 0.30	12.26 ± 0.14	27.04 ± 0.50

during the period of storage at room temperature is given in Table 4. The parameters like Hardness1, Hardness 2, Cohesiveness, Springiness, Gumminess and chewiness were measured at regular intervals of 30 days until spoilage occurred. Hardness 1, hardness 2, springiness, gumminess and chewiness showed a decreasing trend which was significant at $p < 0.05$. The cohesiveness values did not show any significant variation with increase in storage time. The changes in the parameters were similar for the product packed in both the packaging materials and no significant difference was observed at $p < 0.05$.A Similar trend where the hardness showed a decrease was reported in the case of guava and mango leather. (Vijayanand *et al*., 2000). An Equilibrium moisture content in the range of 10 to 15 per cent corresponding to a relative humidity of 59 to 69 per cent is considered best suitable for a product in terms of texture and acceptability. When the moisture content is above 15 per cent the product becomes soft leading to a decrease in hardness and leads to microbial spoilage. (Nanjundaswamy *et al.*, 1976).

Sensory evaluation:

A trained sensory panel evaluated the quality of the product in the two different packaging materials and scores were allotted based on acceptability. The sensory scores of all the attributes (Table 5) did not show any significant variation between the two packaging materials. The products packed in both the packaging materials showed similar results. In both the packaging materials the sensory parameters started showing significant difference at $p < 0.05$ from the 15th day onwards. But

Table 4: Textural changes in jackfruit leather during storage

Storage time in days	Type of packaging material	Hardness 1 (N)	Hardness 2 (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (Nmm)
0	Met PE	37.44 ± 1.68	34.88 ± 0.35	0.083 ± 0.003	1.499 ± 0.006	3.17 ± 0.15	4.75 ± 0.22
30		34.134 ± 0.48	31.52±0.35	0.085±0.004	1.343±0.038	2.93±0.099	3.93±0.17
60		28.84±0.38	23.36±0.86	0.085±0.004	1.35±0.037	2.47±0.16	3.34±0.12
90		20.89±0.53	13.85±0.64	0.08±0.003	1.38±0.02	1.74±0.09	2.39±0.14
0	BOPP	37.44 ± 1.68	34.88 ± 0.35	0.083 ± 0.003	1.499 ± 0.006	3.17 ± 0.15	4.75 ± 0.22
30		32.565±0.63	31.17±0.77	0.084±0.003	1.339±0.026	2.76±0.014	3.7±0.26
60		27.85±1.39	23.65±1.01	0.083±0.004	1.355±0.016	2.3±0.09	3.12±0.15
90		20.69±0.52	14.71±0.05	0.08±0.005	1.36±0.04	1.75±0.14	2.38±0.19

Table 5: Sensory score of jackfruit leather during storage

Storage time in days	Type of packaging material	Taste	Odour	Texture	Appearance	Overall acceptability
0		8.89 ± 0.33	8.56 ± 0.53	8.67 ± 0.5	9 ± 0	8.78 ± 0.2
15		8.56 ± 0.53	8.11 ± 0.33	8.44 ± 0.53^{a}	8.89 ± 0.33^{a}	8.5 ± 0.32^{a}
30	Metalised	8.33 ± 0.5^{a}	7 ± 0.71	8.11 ± 0.78^{a}	8.56 ± 0.53^{a}	8 ± 0.69^{a}
45	polyester/PE	8.33 ± 0.5^{a}	6.56 ± 0.53^{a}	7.89 ± 0.78^{a}	8.44 ± 0.53^{a}	7.81 ± 0.86^{a}
60	laminate	7.89 ± 0.33^{a}	6.22 ± 0.44^{a}	7.56 ± 0.88^{a}	7.11 ± 0.6^{a}	7.2 ± 0.72^{a}
75		6.78 ± 0.97^{a}	5.11 ± 0.6^{a}	7.44 ± 0.88^{a}	5.78 ± 0.67^{a}	6.28 ± 1.04^{a}
90		5.89 ± 0.6^{a}	4.33 ± 0.5^{a}	6.67 ± 0.71^{a}	4.78 ± 0.67^{a}	5.42 ± 1.06^{a}
0		8.89 ± 0.33	8.56 ± 0.53	8.67 ± 0.5	9 ± 0	8.78 ± 0.2
15		8.33 ± 0.71^{a}	8 ± 0.5	8.56 ± 0.53^{a}	8.89 ± 0.33	8.45 ± 0.38
30		8.33 ± 0.5^{a}	6.89 ± 0.6	8.11 ± 0.78^{a}	8.44 ± 0.73^{a}	7.94 ± 0.71^{a}
45	BOPP	8.33 ± 0.5^{a}	6.56 ± 0.53	8.11 ± 0.78^{a}	8.33 ± 0.5^{a}	7.83 ± 0.85^{a}
60		7.67 ± 0.71^{a}	6.22 ± 0.44^{a}	7.67 ± 0.87^{a}	7.11 ± 0.6^{a}	7.17 ± 0.68^{a}
75		6.89 ± 1.05^{a}	5.22 ± 0.67^{a}	7.56 ± 0.88^{a}	5 ± 0.71^{a}	6.17 ± 1.25^{a}
90		5.78 ± 0.67^{a}	4.33 ± 0.5^{a}	6.44 ± 0.73^{a}	4.11 ± 0.6^{a}	5.17 ± 1.13^{a}

the scores were well within the acceptable limits till the 90th day of storage after which microbial spoilage was observed.

Conclusion:

Jackfruit which is a delicacy in the form of a fruit as well as a vegetable is a highly perishable commodity. This study helped us to develop jackfruit leather that replicates the original taste of the fruit. The product had high amount of potassium and sodium. The water activity of the product was 0.47. The shelf-life analysis of the product packed in two different packaging materials (220-gauge polyethylene laminated with 50-gauge metalized polyester and 150 gauge BOPP laminated with 50-gauge polyester) was carried out at room temperature (28±2°C). During the period of storage, the pH of the product showed a slight decrease, titratable acidity was found to increase and there was a decrease in the amount of sugar. The color of the product was analyzed and significant decrease in the L* and b* values were observed whereas a* values did not show any significant variations. The texture profile analysis also showed a decrease in the hardness of the product during storage. The sensory score of the product for the parameters like taste, odor, texture and appearance decreased significantly but was within the acceptable range till 90 days of storage. Thus, jackfruit leather developed was found to have a shelf life of 90 days at room temperature (28±2°C) and all the changes that occurred was similar for the product packed in both the packaging materials which shows that both are suitable for the product.

Acknowledgement:

The authors are thankful to Kerala University of Fisheries and Ocean Studies for the financial support provided to carry out the work. We acknowledge the whole hearted support and guidance given by The Vice Chancellor, Kerala University of Fisheries and Ocean Studies.

LITERATURE CITED

AACC (2000). *Approved methods of American Association of Cereal Chemists.* AACC. Inc., St. Paul, Minnesota, 02-52, 10-10B.

Al-Hinai, K. Z., Guizani, N., Singh, V., Rahman, M. S. and Al-Subhi, L. (2013). Instrumental texture profile analysis of date-tamarind fruit leather with different types of hydrocolloids. *Food Science & Technology Research,* **19** (4) : 531-538.

Al-Muhtaseb, A.H., McMinn, W.A.M., Magee, T.R.A. (2002). Moisture sorption isotherm characteristics of food products: A Review. *Transactions of The Inst. Of Chemical Engineers, —Food & Bioproducts Processing*, **80** (Part C) 118–128.

Antoine, J. M., Fung, L.A.H., Grant, C. N., Dennis, H. T. and Lalor, G. C. (2012). Dietary intake of minerals and trace elements in rice on the Jamaican market. *J. Food Composition & Analysis,* **26** (1-2) : 111-121.

AOAC (1990). *Association of Official Analytical Chemists – AOAC*. Official methods of analysis. 15th (Ed). Arlington.

AOAC (2000). *Official methods of analysis*. Association of Official Analytical Chemists.

Appel, L. J., Baker, D., Bar-Or, O., Minaker, K. L., Morris, R.C., Resnick, L.M. and Whelton, P. K. (2005). Dietary reference intakes for water, potassium, sodium, chloride and sulfate. Institute of Medicine, Washington, D.C., U.S.A.

Ayotte, E. (1980). Fruit leather, Publication no. P-228, University of Alaska Cooperative Extension Service, Fairbanks, Alaska, U.S.A.

Babalola, S. O., Ashaye, O. A., Babalola, A. O. and Aina, J. O. (2002). Effect of cold temperature storage on the quality attributes of pawpaw and guava leathers. *African J. Biotechnology*, **1** (2) : 61-63.

Brian Kateman (2019). This Ancient 'Miracle Fruit' Is The Latest Meat Replacement Craze. Forbes. Retrieved 2 September 2019.

Che Man, Y.B. and Taufik (1995). Development and stability of Jackfruit leather. *Trop. Sci*., **35**(3): 245-250.

Che Man, Y. B. and Sanny, M. M. (1998). Stability of jackfruit leather in different packaging materials 1996. *Asean Food J. (Malaysia),* **11** (4): 163-168.

Chin, S.K., Siew, E.S. and Soon, W.L. (2015). Drying characteristics and quality evaluation of kiwi slices under hot air natural convective drying method. *Internat. Food Res. J.,* **22**(6): 2188-2195.

Chuzel, G. and Zakhia, N. (1991). Adsorption isotherms of gari for estimation of packaged shelf-life. *Int. J. Food Science & Technology,* **26** : 583–593.

Cruz, A.C., Guiné, R. P. F. and Gonçalves, J. C. (2015). Drying kinetics and product quality for convective drying of apples (cvs. Golden Delicious and Granny Smith). *Internat. J. Fruit Sci.,* **15** (1): 54–78.

Dare, P.J. and Edwards, D.B. (1975). Seasonal changes in flesh weight and biochemical composition of mussels (*Mytilusedulis* L.) in the Conwy Estuary, North Wales. *J. Exp. Mar. Biol. Ecol*., **18**: 89-97.

Doymaz, I. (2004). Effect of dipping treatment on air drying of plums. *J. Food Engg*., **64**(4) : 465–470.

Goldenberg, Suzanne (2014). Jackfruit heralded as 'miracle' food crop. The Guardian, London, UK. Retrieved 17 October 2016.

Guiné, R.P.F., Lopes, P., Barroca, M. J. and Ferreira, D.M.S. (2008). Effect of ripening stage on the solar drying kinetics and properties of *S. Bartolomeu pears* (*Pirus Communis* L.). *Internat. J. Academic Research,* **1**(1) : 46– 52.

Guiné, R. (2010). Analysis of the drying kinetics of S. Bartolomeu pears for different drying systems. *E-J. Environmental, Agricultural & Food Chemistry*, **9** (11): 1772–1783.

Gujral, H.S. and Khanna, G. (2002). Effect of skim milk powder, soy protein concentrates and sucrose on the dehydration behaviour, texture, colour and acceptability of mango leather. *J. Food Engg.*, **55** (4) : 343-348.

Hortwitz, W. (1960). *Official methods of analysis*, 8th Ed. Associates of Official Agriculture Chemists Inc. Washington, D.C., U.S.A.

Huang, X. and Hsieh, F.H. (2005). Physical properties, sensory attributes, and consumer preference of pear fruit leather, *J. Food Science*, **70** (3) : E177–E186.

Ikhu-Omoregbe, D. I. O. (2006). Comparison of the sorption isotherm characteristics of two cassava products. *Internat. J. Food Properties*, **9** (2) : 167-177.

Institute of Medicine (US) Standing Committee on the Scientific Evaluation of Dietary Reference Intakes (1997). Dietary reference intakes for calcium, phosphorus, magnesium, vitamin D, and fluoride. National Academies Press (US) International, 17th Ed. Gaithersburg, M.D.

Irwandi, J., Man, Y. C., Yusof, S., Jinap, S. and Sugisawa, H. (1998). Effects of type of packaging materials on physico-chemical, microbiological and sensory characteristics of durian fruit leather during storage. *J. Sci. Food & Agric.,* **76** (3) : 427-434.

Janick, J. and Paull, R.E. (2008). (Eds.)The encyclopedia of fruit and nuts. CABI. Silver, Mark. "Here's The Scoop On Jackfruit, A Ginormous Fruit to Feed The World" NPR. Retrieved 19 April 2008.

Jowitt, R., Escher, F., Hallstrom, B., Meffert, H.F. th., Spiess, W. and Vos, G. (1983). *Physical properties of foods*. Applied Science, London, United Kingdom.

Koubová, E., Sumczynski, D., Šenkárová, L., Orsavová, J. and Fišera, M. (2018). Dietary intakes of minerals, essential and toxic trace elements for adults from eragrostistef L.: *A Nutritional Assessment. Nutrients,* **10**(4) : 479.

Krokida, M.K. and Marinos-Kouris, D. (2003). Rehydration kinetics of dehydrated products. *J. Food Engg.,* **57**(1): 1–7.

Labuza, T.P.(1968). Sorption phenomena in foods. *Food Technology* , **22** : 263–272.

Lane and Eynon (1923). Determination of reducing sugars by means of Fehling's solution with methylene blue as internal indicator. *J. Society of Chemical Industry,* **42** : 32T-37T.

Maskan, A., Kaya, S. and Maskan, M. (2002). Hot air and sun drying of grape leather (pestil). *J. Food Engg.*, **54** (1) : 81–88.

Matin, Abdul (2015). *A poor man's fruit: Now a miracle food*!". The Daily Star. Retrieved 2015-06-12.

Morgano, M. A., Rabonato, L. C., Milani, R. F., Miyagusku, L. and Balian, S.C. (2011). Assessment of trace elements in fishes of Japanese foods marketed in São Paulo (Brazil). *Food Control*, **22** (5) : 778-785.

Morton, Julia (2016). "Jackfruit". *Center for new crops & plant products, Purdue University Department of Horticulture and Landscape Architecture*. Retrieved 19 April 2016.

Moyls, L. (1981). Drying of apple puree, *J. Food Science*, **46** : 939 – 942.

Muliterno, M.M.,Rodrigues, D., de Lima, F. S., Ida, E. I. and Kurozawa, L.E. (2017). Conversion/degradation of isoflavones and colour alterations during the drying of okara," LWT - *Food Science and Technology,* **75**: 512–519.

Nanjundaswamy, A. M., Radhakrishnaiah Shetty, G. and Saroja, S. (1976). Studies on development of newer products from mango. *Indian Food Packer,* **5**: 95-103.

Ofuya, C.C. and Akpoti, P. (1988). Post-processing microflora and shelf-life stability of gari marketed in Port Harcourt, Nigeria. *J. Appl. Bacteriol.,* **64** (5): 389–394.

Ong, B. T., Nazimah, S. A. H., Osman, A., Quek, S. Y., Voon, Y. Y., Hashim, D. M. and Kong, Y.W. (2006). Chemical and flavour changes in jackfruit (*Artocarpus heterophyllus* Lam.) cultivar J3 during ripening. *Postharvest Biology & Technology,* **40** (3) : 279-286.

Raab, C. and Oehler, N. (1976). *Making dried fruit leather, fact sheet 232*, Oregon State University Extension Service, Tillamook, Ore, U.S.A.

Raman, M., Dinakaran, A., Ravindran, A., Sankar, T. V. and Gopal, T. K. S. (2019). Dietary spplementation of κ-Carrageenan to improve the physio-chemical and functional properties of white bread. *Food & Nutrition Sciences*, **10** (08): 997.

Rao, V. S. and Roy, S.K. (1980). Studies on dehydration of mango pulp. I: standardization for making mango sheet/ leather. *Indian Food Packer,* **34** (3) : 64-71.

Sacilik, K. and Elicin, A.K. (2006). The thin layer drying characteristics of organic apple slices. *J. Food Engg.,* **73** (3) : 281-289.

Sadler, G. D. and Murphy, P. A. (2010). pH and titratable acidity. In: *Food analysis* (pp. 219-238). Springer, Boston, M.A.

Sahin, A.Z. and Dincer, I. (2005). Prediction of drying times for irregular shaped multi-dimensional moist solids. *J. Food Engg.,* **71** (1)119-126, DOI:10.1016/ j.jfoodeng.2004.10.024

Sanni, M.O. (1996). The stability of stored gari. *Internat. J. Food Microbiology,* **29** (1) : 119–123.

Selvaraj, Y. and Pal, D.K. (1989). Biochemical changes during ripening of jackfruit (*Artocarpus heterophyllus* L.). *J. Food Sci. Tech.,* **26** : 304–307.

Seow, C.C., Teng, T. T. and Quah, C. H. (1988). (Eds.) *Food preservation by moisture control*. Amsterdam: Elsevier Applied Science.

Subrahmanian, N., Hikosaka, Shu, Samuel, G. John and Thiagarajan, P. (1997). Tamil social history. Institute of Asian Studies. p. 88. Retrieved 2010-03-23.

Trumbo, P., Yates, A. A., Schlicker, S. and Poos, M. (2001). Dietary reference intakes: vitamin A, vitamin K, arsenic, boron, chromium, copper, iodine, iron, manganese, molybdenum, nickel, silicon, vanadium and zinc. *J. Academy of Nutrition & Dietetics*, **101** (3) : 294.

Tyl, C. and Sadler, G. D. (2017). pH and titratable acidity. In *Food analysis* (pp. 389-406). Springer, Cham.

Ukhun, M.E. and Dibie, E.N. (1991). The ascorbic acid contents of selected marketed foods and influence of water activity (aw) during storage. *Food Chemistry* , **41** (3) : 277–283.

Unal, H.G. and Sacilik, K. (2011). Drying characteristics of hawthorn fruits in a convective hotair dryer. *J. Food Processing & Preservation*, **35**(2) : 272-279.

Vijayanand, P., Yadav, A. R., Balasubramanyam, N. and Narasimham, P. (2000). Storage stability of guava fruit bar prepared using a new process. *LWT-Food Science & Technology*, **33** (2) : 132-137.

Wankhade, P.K., Sapkal, R.S. Sapkal, V.S. (2013). Drying characteristics of okra slices on drying in hot air dryer. *Procedia Engineering,* **51** : 371-374.

Received : *18.07.2020;* **Revised :** *26.08.2020;* **Accepted :** *26.09.2020*